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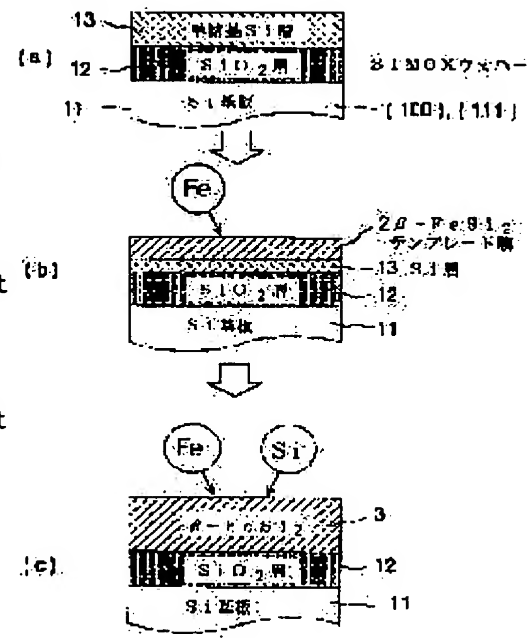
(54) PRODUCTION OF THIN '-FESI2 FILM AND DEVICE WITH THE SAME

(57)Abstract:

PURPOSE: To produce a thin β-$FeSi_2$ film having excellent thermoelectric conversion characteristics and to obtain a thin β-$FeSi_2$ film device.

CONSTITUTION: A single crystalline silicon layer 13 is formed on a single crystalline silicon substrate 11 with interposing an insulating film 12 and iron is deposited by PVD on the silicon layer 13 and brought into a solid phase reaction with the silicon layer 13 to form the objective thin single crystalline β-$FeSi_2$ film 13. In other way, at least iron is deposited by PVD on the single crystalline silicon substrate, the objective thin single crystalline β-$FeSi_2$ film is formed, the silicon substrate is joined to an insulating substrate to form a stuck substrate and the excess single crystalline silicon part of the silicon substrate is removed.



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CLAIMS

[Claim(s)]
[Claim 1] Beta-FeSi 2 characterized by making iron deposit by PVD on the single-crystal-silicon layer formed on both sides of the insulator layer on the single crystal silicon substrate, carrying out solid phase reaction of said iron and said single-crystal-silicon layer, and forming the iron silicide (beta-FeSi 2) thin film of a single crystal The manufacture approach of a thin film.
[Claim 2] Beta-FeSi 2 according to claim 1 which carries out epitaxial growth of the iron silicide (beta-FeSi 2) thin film further on said iron silicide (beta-FeSi 2) thin film The manufacture approach of a thin film.
[Claim 3] Said iron silicide (beta-FeSi 2) thin film is beta-FeSi 2 according to claim 1 which touches said insulator layer. The manufacture approach of a thin film.
[Claim 4] Beta-FeSi 2 characterized by depositing iron by PVD at least on a single crystal silicon substrate, forming the iron silicide (beta-FeSi 2) thin film of a single crystal, joining said single crystal silicon substrate to the front face of the insulating substrate with which a front face consists of an electrical insulator at least, removing the single-crystal-silicon part of said single crystal silicon substrate, and exposing and forming said iron silicide (beta-FeSi 2) thin film on said insulating substrate The manufacture approach of a thin film.
[Claim 5] Beta-FeSi 2 characterized by having the insulating substrate with which the surface section serves as an insulator layer at least, and the iron silicide (beta-FeSi 2) thin film of the single crystal formed on said insulating substrate Equipment which has a thin film.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the equipment which has the manufacture approach of an iron silicide (beta-FeSi 2) thin film, and beta-FeSi 2 thin film, and is beta-FeSi 2 of a single crystal in detail. The manufacture approach of a thin film, and beta-FeSi 2 of a single crystal It is related with the equipment which has a thin film.
[0002]
[Description of the Prior Art] Beta-FeSi 2 A thin film (henceforth an iron silicide thin film) is alpha-FeSi 2 which has the structure of a prismatic crystal among iron silicide structure systems, and has hexagonal structure. It is distinguished. Beta-FeSi 2 Having the outstanding heat-electric resistance property is known. JP,4-210463,A is indicating that dispersion in a thermistor constant becomes small by making substrate temperature at the time of deposition into 200-600 degrees C on the occasion of an alumina substrate top depositing the iron silicide (beta-FeSi 2) film of polycrystal by PVD, and annealing at 500-900 degrees C after that.
[0003] Moreover, depositing iron by PVD and forming an iron silicide (beta-FeSi 2) thin film with heteroepitaxial growth on a single crystal silicon substrate, is also proposed.
[0004]
[Problem(s) to be Solved by the Invention] However, above-mentioned beta-FeSi 2 Since the thin film had polycrystal structure, its carrier mobility was low, for the reason, it had the fault that a heat-electric resistance property (thermoelectrical conversion sensibility) was low, and had the fault that dispersion in a property was still larger. On the other hand, when an iron silicide (beta-FeSi 2) thin film was formed on a single crystal silicon substrate, there was fault from which the electric resistance between an iron silicide (beta-FeSi 2) thin film and a single crystal silicon substrate or the electric resistance of a single crystal silicon substrate joins own electric resistance of an iron silicide (beta-FeSi 2) thin film at juxtaposition, therefore it becomes difficult to detect resistance change of the iron silicide (beta-FeSi 2) thin film itself.
[0005] Beta-FeSi 2 which has the heat-electric resistance property of it having been made in view of the above-mentioned problem, and having excelled in this invention Beta-FeSi 2 which sets it as the 1st purpose to offer the manufacture approach of a thin film, and has the outstanding heat-electric resistance property It sets it as the 2nd purpose to offer equipment with a thin film, and is.
[0006]
[Means for Solving the Problem] Beta-FeSi 2 of the 1st invention The manufacture approach of a thin film is characterized by making iron deposit by PVD on the single-crystal-silicon layer formed on both sides of the insulator layer on the single crystal silicon substrate, carrying out solid phase reaction of said iron and said single-crystal-silicon layer, and forming the iron silicide (beta-FeSi 2) thin film of a single crystal.
[0007] In a suitable mode, epitaxial growth of the iron silicide (beta-FeSi 2) thin film is further carried out on said iron silicide (beta-FeSi 2) thin film. In a suitable mode, said iron silicide (beta-FeSi 2) thin film touches said insulator layer. Beta-FeSi 2 of the 2nd invention The manufacture approach of a thin film On a single crystal silicon substrate, deposit iron by PVD at least and the iron silicide (beta-FeSi 2) thin film of a single crystal is formed. It is characterized by joining said single crystal silicon substrate to the front face of the insulating substrate with which a front face consists of an electrical insulator at least, removing the single-crystal-silicon part of said single crystal silicon substrate, and exposing and forming said iron silicide (beta-FeSi 2) thin film on said insulating substrate.

[0008] Beta-FeSi 2 of the 3rd invention The equipment which has a thin film is characterized by having the insulating substrate with which the surface section serves as an insulator layer, and the iron silicide (beta-FeSi 2) thin film of the single crystal formed on said insulating substrate at least.
[0009]
[Function and Effect(s) of the Invention] Beta-FeSi 2 of the 1st invention By the manufacture approach of a thin film, using the so-called substrate of the silicon on insulator (S0I) structure where the single-crystal-silicon layer was formed on both sides of the insulator layer on the single crystal silicon substrate, iron is made to deposit by PVD on this, solid phase reaction of iron and the single-crystal-silicon layer is carried out, and the iron silicide (beta-FeSi 2) thin film of a single crystal is formed.
[0010] thus, if it carries out, since an iron silicide (beta-FeSi 2) thin film will serve as a single crystal, it can have the heat-electric resistance property (thermoelectrical conversion sensibility) of it having been markedly alike compared with the iron silicide (beta-FeSi 2) thin film of the conventional polycrystal, and carrier mobility having been excellent, and having excelled for the reason, and dispersion in a property can also manufacture the iron silicide (beta-FeSi 2) thin film of a small single crystal. And since this iron silicide (beta-FeSi 2) thin film is electrically insulated from a single crystal silicon substrate by the insulator layer, in case the electric resistance of an iron silicide (beta-FeSi 2) thin film is detected, the electric resistance of a single crystal silicon substrate is not included in the electric resistance of an iron silicide (beta-FeSi 2) thin film.
[0011] Namely, beta-FeSi 2 in which dispersion has the heat-resistive characteristic of high sensitivity few since the silicon layer on an insulator layer is single-crystal-ized based on the single crystal structure of a single crystal silicon substrate and the iron silicide (beta-FeSi 2) thin film of a single crystal is formed in this invention according to the solid phase reaction of this single-crystal-silicon layer and a PVD iron layer The manufacture approach of a thin film is realizable.
[0012] In the suitable mode of the 1st invention, epitaxial growth of the iron silicide (beta-FeSi 2) thin film is further carried out on the iron silicide (beta-FeSi 2) thin film which grew according to the above-mentioned solid phase reaction. The iron silicide (beta-FeSi 2) thin film (henceforth a base film) formed of the above-mentioned solid phase reaction is that to which crystal quality falls with the increment in thickness (when it exceeds especially 50nm), supplies iron and silicon at a rate of 1 to 2 by the atomic ratio on this base film formed thinly, and grows epitaxially further an iron silicide (beta-FeSi 2) thin film.
[0013] If it does in this way, use will be faced, and it is single crystal beta-FeSi 2 of suitable thickness (50nm or more). A thin film can be formed on an insulator layer. In the suitable mode of the 1st invention, an iron silicide (beta-FeSi 2) thin film touches an insulator layer. If it does in this way, the electric resistance of a single-crystal-silicon layer will not be connected to the electric resistance of an iron silicide (beta-FeSi 2) thin film, and juxtaposition, and the heat-electric resistance property of an iron silicide (beta-FeSi 2) thin film will serve as high sensitivity further.
[0014] Beta-FeSi 2 of the 2nd invention The manufacture approach of a thin film deposits iron by PVD at least on a single crystal silicon substrate, forms the iron silicide (beta-FeSi 2) thin film of a single crystal, joins this single crystal silicon substrate to an insulating substrate, uses it as a lamination substrate, and removes a single-crystal-silicon part with an excessive single crystal silicon substrate. thus, if it carries out, since an iron silicide (beta-FeSi 2) thin film will serve as a single crystal, it can have the heat-electric resistance property (thermoelectrical conversion sensibility) of it having been markedly alike compared with the iron silicide (beta-FeSi 2) thin film of the conventional polycrystal, and carrier mobility having been excellent, and having excelled for the reason, and dispersion in a property can also manufacture the iron silicide (beta-FeSi 2) thin film of a small single crystal. And since this iron silicide (beta-FeSi 2) thin film is formed on an insulating substrate, in case the electric resistance of an iron silicide (beta-FeSi 2) thin film is detected, the electric resistance of a substrate can be disregarded, and the above-mentioned heat-electric resistance property does not deteriorate.
[0015] In addition, an insulator substrate like an alumina is sufficient as an insulating substrate, or the substrate with which only the surface section like a single crystal silicon substrate which has silicon oxide on a front face has electric insulation is sufficient as it. beta-FeSi 2 of the 3rd invention the equipment which has a thin film -- for example, beta-FeSi 2 formed by the above-mentioned manufacture approach the electric apparatus which has a thin film -- it is -- conventional polycrystal beta-FeSi 2 Beta-FeSi 2 formed on the thin-film device or the single crystal silicon substrate As compared with a thin-film device, it becomes equipment which has the heat-

electric resistance conversion sensibility which was markedly alike for the above-mentioned reason, and was excellent.
[0016] It consists of a single crystal silicon substrate to which an insulating substrate has an insulator layer on a front face in a suitable mode, a single-crystal-silicon layer is arranged on an insulator layer, and it is beta-FeSi 2 to a single-crystal-silicon layer. The sense circuit which processes the output signal of a thin film is formed. If it does in this way, the equipment which has the heat-electric resistance property of high sensitivity further is realizable.
[0017] namely, -- this equipment -- beta-FeSi 2 a thin film -- adjoining -- that sense circuit (amplifier) -- it can prepare -- beta-FeSi 2 the electromagnetism which the signal line which connects a thin film, i.e., a thermal element, and a sense circuit becomes very short, and can reduce the thermal noise voltage resulting from the electric resistance of this signal line, and is guided to this signal line -- a noise electrical potential difference can also be reduced.
[0018]
[Example]
(Example 1) Beta-FeSi 2 of the following and the 1st invention An example of the manufacture approach of a thin film is explained with reference to drawing 1 . First, as shown in drawing 1 (a), the SIMOX wafer [that at least the method (111) of a field (100) is desirable (111)] (dielectric separation Si substrate which uses as a dielectric the oxide film formed by the oxygen ion implantation) 1 is prepared. This SIMOX wafer 1 consists of the single crystal silicon substrate 11, a silicon oxidation membrane layer 12 formed by impregnation and heating of oxygen ion on it, and a single-crystal-silicon layer 13 on it.
[0019] Next, this single-crystal-silicon layer 13 is etched, and about 10-50nm of that thickness is preferably set to 10-30nm. This is for improving the crystallinity of the iron silicide (beta-FeSi 2) thin film of the single crystal formed from this single-crystal-silicon layer 13. Etching is suitable because of the homogeneous improvement of thickness in the approach of etching the thermal oxidation film (not shown) which oxidized thermally and formed the single-crystal-silicon layer 13 by rare fluoric acid. Of course, multiple-times operation is possible for this etching process.
[0020] Next, Fe layer is deposited by the sputtering method (other PVD is sufficient) on the single-crystal-silicon layer 13. For deposited Fe layer, at the time immediately after deposition, a part is beta-FeSi 2. Although the remainder serves as Fe layer, since it is easy here, it is beta-FeSi 2 about a deposit. It is called the template film 2. In addition, this beta-FeSi 2 The crystal structure of the iron silicide (FeSi2) layer in the template film 2 is regulated by field bearing (here 111) of the single-crystal-silicon layer 13, and field bearing serves as single crystal beta-FeSi 2 structure of (101) (refer to drawing 1 (b)). Sputtering is Ar+ in a high vacuum (base degree of vacuum - 10 -5 Pa, deposition medium vacuum whenever - 10 -3 Pa). It carried out by the ion sputtering method. It was made for the deposition thickness of Fe layer to be set to Fe:Si=15:53 to the thickness of the single-crystal-silicon layer 13. Moreover, substrate temperature under deposition was made into 625-725 degrees C.
[0021] Next, beta-FeSi 2 On the template film 2, 1 to 2 comes out of Fe and Si comparatively by the atomic ratio further, and it is Ar+ simultaneously. It is made to deposit by the ion sputtering method. Similarly substrate temperature is made into 625-725 degrees C. Thereby, also for this deposit, a part is beta-FeSi 2. The remainder serves as Fe layer. All beta-FeSi 2 Thickness could be about 50nm. Then, grade annealing is carried out for 60 minutes at the substrate temperature of 625-725 degrees C within a vacuum chamber, and it is beta-FeSi 2 of a single crystal about all deposits. It considers as a thin film 3 (refer to drawing 1 (c)).
[0022] When the conditions of Fe and Si coincidence ion spatter are indicated further, for the distance of Fe target and a substrate, the distance of 200mm, Si target, and a substrate is [both the 1.5kV and moderation electrical potential differences of the acceleration voltage of 200mm and Ar+ spatter gun] 0.5kV. Moreover, arc voltage is 61V and an arc current controls the rate of sedimentation for Fe and Si as Fe 0.6-1.2A and Si1.2A. As for especially the rate of sedimentation of Fe and Si, it was respectively optimal that Fe considered as a part for 3.7nm/, and Si considered as a part for 14nm/by part [for 3.7-6.0nm/] and 13-15nm/. These rates of sedimentation take into consideration stoichiometric composition of the iron silicide (beta-FeSi 2) film.
[0023] In addition, the after [deposition] process which 1 to 2 comes out comparatively and deposits above-mentioned Fe and Si simultaneously in an atomic ratio, and a subsequent annealing process can be skipped. However, when skipping an annealing process, it is desirable to carry out a sputtering deposition process

(drawing 1 (b)) slowly. Namely, by making substrate temperature at the time of deposition and subsequent annealing into 625-725 degrees C Deposited Fe layer reacts with the single-crystal-silicon layer 13 by the annealing treatment of under deposition and after that, and turns into an iron silicide (FeSi2) layer. For the crystal structure of this iron silicide (FeSi2) layer, it is regulated by field bearing (here 111) of the original single-crystal-silicon layer 13, and field bearing is beta-FeSi 2 of the single crystal of (101). It becomes a thin film 2. In addition, beta-FeSi 2 of a single crystal It is 1.4% of rates of grid mismatching of a thin film 3 and the single-crystal-silicon layer 13. Moreover, beta-FeSi 2 The single crystal nature of a thin film 2 is excellent especially when thickness is set to about 50nm or less.

[0024] Beta-FeSi 2 of drawing 1 (b) In order to set the template film 2 to 50nm finally, it is desirable to be referred to as about 15nm, assuming Fe layer which deposits about 53nm of sum totals of the deposition thickness of the single-crystal-silicon layer 2 and Si layer supplied with Fe to be unreacted.

(Example 2) others -- an example is explained with reference to drawing 2 .

[0025] In this example, until it becomes lamination about the single crystal silicon substrate 4 and becomes the thickness of same extent as the single-crystal-silicon layer 13 of an example 1 about the single crystal silicon substrate 4 on both sides of silicon oxide 12 on the single crystal silicon substrate 11 It grinds and etches, a lamination substrate is formed (drawing 2 (a)), and subsequent processes are beta-FeSi 2 on (drawing 2 (b)) and silicon oxide 12 as the same as an example 1. The thin film 3 was formed (drawing 2 (c)).

[0026] Hereafter, if the manufacture approach of this lamination substrate is explained, after giving mirror polishing to one principal plane of the single crystal silicon substrate 11, thermal oxidation will be given and silicon oxide 12 will be formed. And the 2nd single crystal silicon substrate 3 which has the principal plane by which mirror polishing was carried out is stuck under an ambient atmosphere pure enough, is heated, and it joins to the silicon oxide 12 side of this single crystal silicon substrate 11 front face. Next, mirror polishing of the single crystal silicon substrate 4 is carried out, it is etched, and a lamination substrate is formed.

(Example 3) others -- an example is explained with reference to drawing 3 .

[0027] In this example, it is beta-FeSi 2 at the same process as the above-mentioned examples 1 and 2 on the single crystal Si substrate 4. On the other hand, the single-crystal-silicon layer 11 which has silicon oxide 12 on a front face is prepared, both [these] the substrates 4 and 11 are stuck, a lamination substrate is formed [a thin film 5 is formed,] (drawing 3 (a)), the single-crystal-silicon part of the single crystal silicon substrate 4 is ground and etched after that, and it is beta-FeSi 2. The thin film 5 was formed.

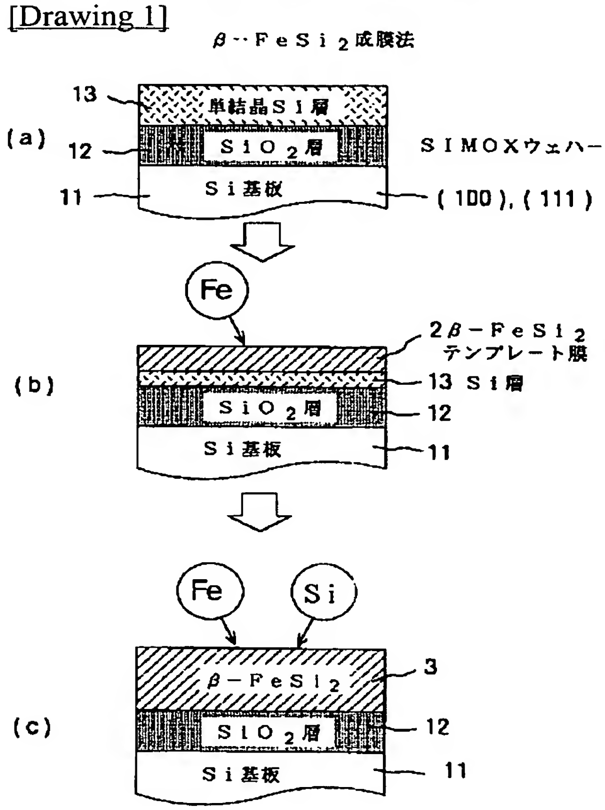
[0028] In addition, the process of a lamination substrate is the same as an example 2. However, silicon oxide 12 performs KYAROSU washing (H2 SO4:H2 O2 =4:1) before lamination, and it is beta-FeSi 2. An organic solvent washes the film 5. And after lamination, it heat-treats in an inert gas ambient atmosphere, and the lamination substrate of drawing 3 (a) is obtained. In addition, it cannot be overemphasized that it is replaceable to insulating substrates, such as an alumina substrate, in the single crystal silicon substrate 11 which has silicon oxide 12 in this case.

[0029] In addition, silicon oxide 12 is minded on the single crystal silicon substrate 11 of the structure of each above-mentioned example, and it is beta-FeSi 2. Since the equipment which has thin films 3 and 5 has single-crystal-silicon SOI structure About the single crystal silicon substrate 11 on the silicon oxide 12 of a SOI substrate, it is beta-FeSi 2. Only a thin film formation schedule field is beforehand etched into predetermined thickness, considers IC formation schedule field as as [the thickness in which IC formation is possible], and is after that. Bipolar ** forms an MOS sense circuit in IC formation schedule field. After that, Beta-FeSi 2 It is beta-FeSi 2 to a thin film formation schedule field. Thin films 3 and 5 are formed. then, beta-FeSi 2 the edge of thin films 3 and 5, and the input edge of the above-mentioned sense circuit -- the conductor on an interlayer insulation film -- a line -- connecting -- a sense circuit and beta-FeSi 2 The semiconductor device (temperature-sensitive equipment) which has a thin film can also be manufactured.

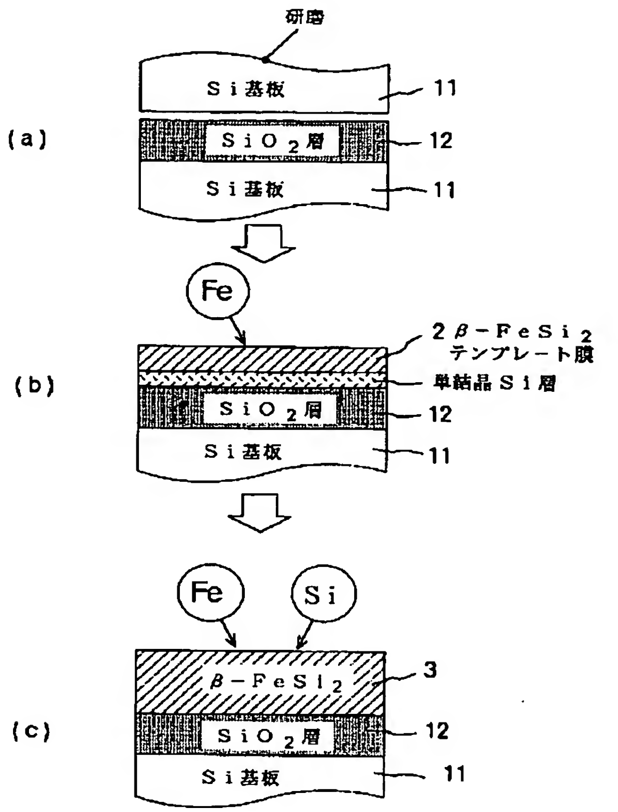
[Translation done.]

DRAWINGS

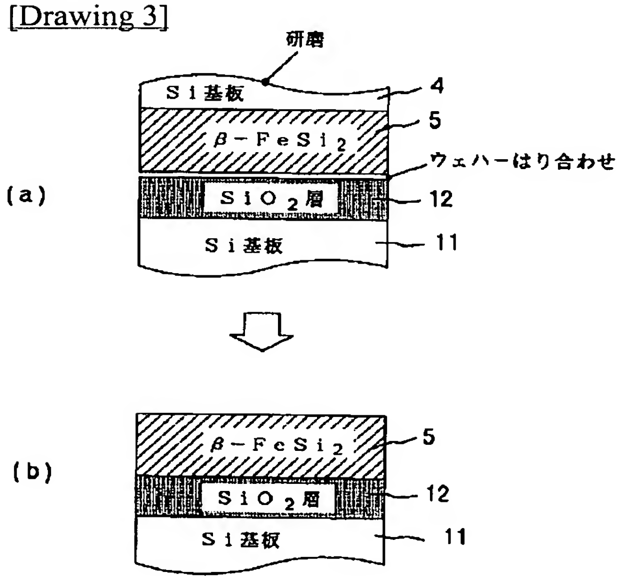
[Drawing 1]



[Drawing 2]



[Drawing 3]



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